THE MURAT LABELS : A GOOD ANSWER TO IM POLICIES - THE EXAMPLE OF THE FRENCH DOCTRINE

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ABSTRACT:

Most of the main nations involved in the ordnance production have nowadays issued IM Policies. The aim of these Policies is to provide an incentive to structure research programs and to develop the technology necessary for production and procurement of IM for service use.

But very often the requirements of these Policies are directed towards a reduction of hazards due to specific threats, as a result of a Threat Hazard Analysis (THA).

The objective of this paper is to demonstrate that MURAT labels may be a good way to guide the development of munitions which:

* will firstly offer the hazard reduction required by the results of THA conducted according to IM Policies

* will also bring a broader guarantee of reduce hazards, even in case of deviation of a threat (for example if bullet velocity is less than the classical 850 m/s)

* will additionally exhibit reduced hazards to threats not taken into account by the THA

* will anticipate possible evolution of threats, life cycle, users

* will allow interoperability

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The demonstration is based on the French Doctrine on MURAT, compared to other national or NATO approaches, with technical arguments coming from tests.

1 INTRODUCTION

Today, a better understanding of the phenomena, the availability of more reliable and more adaptable materials and concepts, and progress in theoretical simulation methods permit a realistic approach to the development of Insensitive Munitions (MURAT in French for Munitions à Risques ATténués or Less Hazardous Munitions).

So time appeared opportune to define a national Doctrine and deliberations conducted since mid 92 between various Departments and Services of the DGA, the Military Staff and industry, have permitted the establishment of a Doctrine which was ratified in August 1993.

This document was established as closed as possible to the various trends observed in the world so that it will facilitate discussions and, as necessary, allow for compromises with our foreign partners.

Nevertheless compared to the others this Doctrine presents some originalities which are described hereafter in order to show how they will bring a good answer to IM policies in terms of:

- response to the requirements emerging from a THA (Threat Hazard Analysis),
- guarantee of reduced hazards, even in case on unidentified threats, and in case of evolution of the threats,
- interoperability,
- incentive for-optimization of research and technology improvement programs.

2/ TYPES OF THREAT/STIMULI TAKEN INTO ACCOUNT IN THE FRENCH DOCTRINE

It could appear interesting to a program manager, for cost saving, to limit the safety requirements of a new munition to specific stimuli and types of reaction defined according to a threat hazard analysis for precise environment and use of this munition.

But for reasons of interoperability (national or international), because service life of a munition can be over 25 years which means that its missions could evolve, because threat environment will evolve, it was chosen to assess the munition according to a predefined list of stimuli and not dependent on a threat hazard

analysis.

The systematic analysis of possible threats for all families of munitions and the different types of life cycle -work which was already done in many occidental countries but also recently more deeply by NIMIC- has shown a common basis of stimuli that munitions could be exposed to during their logistic and operational life, in peace time as well as in crisis time, even if related scope of stimuli can slightly vary from one to the other.

So we selected a list of 9 stimuli that are representative of these conditions. These are the ones for which the candidate Insensitive Munition reactions will be analyzed:

1 - severe electrical and electromagnetic stimuli
2 - drop

Those 2 firsts correspond in fact to the baseline acceptance criteria in service use for which it is required no reaction at all and are indicated as a reminder.

3 - external fire
4 - slow heating
5 - bullet impact

Those correspond to the classical mechanical and thermal stimuli.

6 - sympathetic reaction (stimuli due to normal or abnormal functioning of a munition)

This allows us to know the potential for the propagation of a disaster induced by one to prejudge the behavior of munitions faced with severe stimuli to which they may be exposed (non-identical munition functioning nearby, impact by fragments from a projectile, from flying rocks or other debris, airplane crash...).

To that list of very fundamental stimuli selected in every policy we added three others more relevant to time of crisis:

7 - impact by light fragments (i.e. corresponding to attack by small warheads and shells)
8 - impact by heavy fragments (i.e. corresponding to attack by large prefragmented warheads)
9 - impact by a shaped charge jet (i.e. corresponding to anti-tank warheads)

3/ THE MURAT LABELS

3.1 Interest of labels

The level of insensitiveness of a munition is evaluated according to the type of reaction when subjected to the selected stimuli.

The ideal munition is the one whose response to unplanned stimuli is never more severe than type V.

Unfortunately this is:

- very expensive
- sometimes uncompatible with a required level of performance
- sometimes also uncompatible for an operational use (if, i.e., it requires large and heavy containers).

That means that, today, most of the time, waivers will have to be given by the national authority.

For -national or international- interoperability/interchangeability and common understanding it was found essential, beside the ultimate MURAT level, to predefine agreed "waiver levels" and to attribute MURAT labels corresponding to the immunity level attained.

Those levels of insensitiveness being directly linked to the available technologies used for the design of munitions - energetic materials, mitigation systems, architecture and concepts, . .. - we also think that more than an unique unaccessible one, such progressive labels will push forward research and development of new products and solutions.

3.2 The french labels

The "ultimate MURAT" label is the ******* label for which the reaction level, for all stimuli, does not exceed combustion or deflagration (excepts for shaped charge jet impact stimuli for which an explosion is permitted).

The "predefined waiver levels" are:

- The MURAT ** label for which only the shaped charge jet impact stimuli produce a detonation. The risk of a mass detonation is excluded.

- The MURAT * label for which the mass detonation by sympathetic reaction is excluded but does not exclude single items detonating following impacts by fragments or shaped charge stimuli.

This lower level will nevertheless ensure that a munition labeled MURAT will not exhibit unacceptable hazards to basic threats.

The stimuli/reaction tables given below define the maximum level of reaction that is acceptable for each stimuli imposed for each degree of insensitiveness.

The MURAT label allows for the characterization of the behavior of a munition exposed to typical stimuli. It does not, in any manner, wave a risk analysis for the conditions in which the munition will be used, any more than the knowledge of the hazard division for storage and transport can replace specific studies for the conditions in which the munition will be used.

When the specific effects of the stimuli generates a much more serious hazard than that potentially presented by the munition examined, we do not plan consider that stimuli.

STIMULI/REACTIONS TABLE
MURAT ★ LABEL

Reactions / Stimuli	NR	V	IV(2)	III	II	I
Electrical	X					
Drop	X(1)					
External fire	X	X	X			
Slow heating	X	X	X	X		
Bullets	X	X	X	X		
Sympathetic reaction	X	X	X	X		
Light fragments	X	X	X	X	X	X
Heavy fragments	X	X	X	X	X	X
Shaped charge jet	X	X	X	X	X	X

(1) : evacuation of the article must be possible with no risk
(2) : no propulsion
Key : X accepted reaction
NR no reaction

STIMULI/REACTIONS TABLE
MURAT ★★ LABEL

Reactions / Stimuli	NR	V	IV(3)	III	II	I
Electrical	X					
Drop	X(1)					
External fire	X	X(2)				
Slow heating	X	X				
Bullets	X	X	X	X		
Sympathetic reaction	X	X	X	X		
Light fragments	X	X	X	X		
Heavy fragments	X	X	X	X		
Shaped charge jet	X	X	X	X	X	X

(1) : evacuation of the article must be possible with no risk
(2) : at the earliest, 5 minutes after the start of the fire
(3) : no propulsion
Key : X accepted reaction
NR no reaction

STIMULI/REACTIONS TABLE
MURAT * LABEL
AND
STIMULI/REACTIONS TABLE
MURAT ** LABEL

STIMULI/REACTIONS TABLE
MURAT ★★★ LABEL

Reactions / Stimuli	NR	V	IV(3)	III	II	I
Electrical	X					
Drop	X(1)					
External fire	X	X(2)				
Slow heating	X	X				
Bullets	X	X				
Sympathetic reaction	X	X	X			
Light fragments	X	X				
Heavy fragments	X	X	X			
Shaped charge jet	X	X	X	X		

(1) : evacuation of the article must be possible with no risk
(2) : at the earliest, 5 minutes after the start of the fire
(3) : no propulsion

Note : defense energetic materials will be of the EIDS (extremely insensitive detonating substance) type with the exception of those located upstream of shutters when such features are in the initiation train.

Key : X accepted reaction
NR no reaction

STIMULI/REACTIONS TABLE
MURAT * LABEL**

3.3 Comparison with other policies

The MURAT label requirements can be compared to those given by other main policies:
US IM requirements (According to DOD MIL-STD-2105 B):

Reactions / Stimuli	NR	V	IV	III	II	I
External fire	X	X				
Slow heating	X	X				
Bullets	X	X				
Sympathetic reaction	X	X	X	X	X	
Light fragments(1)	X	X				
Heavy fragments						
Shaped charge jet(1)	X	X	X	X	X	
Spall(1)	X	X				

(1) : according to threat hazard analysis

NATO AC 310 draft stanag 4439
Policy for introduction assessment and testing for insensitive munitions (MURAT)
Requirements Goals

Reactions / Stimuli	NR	V	IV	III	II	I
External fire	X	X				
Slow heating	X	X				
Bullets	X	X				
Sympathetic reaction	X	X	X	X		
Light fragments	X	X				
Heavy fragments						
Shaped charge jet	X	X	X	X		
Spall	X	X				

UN

Class 1.6 for transport of dangerous goods

Reactions / Stimuli	NR	V	IV	III	II	I
External fire	X	X				
Slow heating	X	X				
Bullets	X	X	X	X		
Sympathetic reaction	X	X	X	X		
Light fragments						
Heavy fragments						
Shaped charge jet						

In addition, Explosive Materials contained in article shave to be EIDS (Extremely Insensitive Detonating Substances).

NATO AC 310 DRAFT STANAG 4439

AND

UN
CLASS 1.6 FOR TRANSPORT OF DANGEROUS GOODS

4/ ASSESSMENT OF BEHAVIORS

4.1 Scope of stimuli

Theoretically, for a type of Threat, the scope of characteristics of associated stimuli is unlimited. It is not possible for the "demonstration of MURAT level" to cover the totality of this scope and so limited scope corresponding to specified range of characteristics were defined for each stimulus.

The choices were based on a combination of:

- the probability of having the characteristics

- the severity of the corresponding stimulus

These choices are done in order to increase the confidence level and the validity of the assessment but again not because of a threat hazard analysis.

The "demonstration of the type of reaction given by a munition subjected to one selected stimuli has to be done at least for those defined scopes:

CATEGORY OF STIMULI	TYPE OF SELECTED STIMULI	SCOPE TO BE TAKEN INTO ACCOUNT FOR THE MURAT ASSESSMENT
Electrical or electromagnetic	1 Severe electrical or electromagnetic stimuli	- electrical or electromagnetic radiation : scope defined in GAM DRAM 01 02 - static electricity : scope defined in STANAG 4235 - lightning : scope defined in STANAG 4236 excluding direct lightning strike
Mechanical	2 Drop	Heights of 0 to 12 m on flat steel surface
Thermal	3 External fire	Liquid hydrocarbon Kerosene type fuel combustion No limitation in time

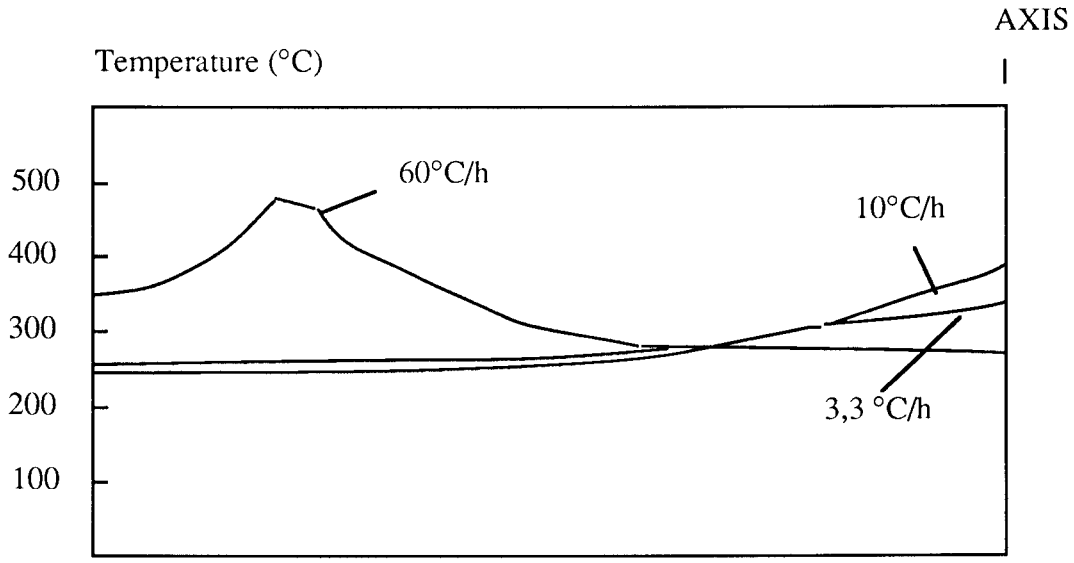
CATEGORY OF STIMULI	TYPE OF SELECTED STIMULI	SCOPE TO BE TAKEN INTO ACCOUNT FOR THE MURAT ASSESSMENT
Thermal	4 Slow heating	Steady heating rate of 3 to 60°C per hour starting from ambient temperature No limitation in time
Mechanical	5 Bullet impacts	0.50 cal. armour-piercing bullets 1 to 3 bullets in burst Impact velocity of 0 to 850 m/s
Mechanical	6 Sympathetic reaction	The most penalizing reaction (nominal or not) of identical munition in the most detrimental for safety configuration
Mechanical	7 Light fragment impacts	20 g cubic steel fragments 3 simultaneous fragments Impact velocities of 0 to 2 000 m/s
Mechanical	8 Heavy fragment impacts	250 g parallelepipedic steel fragment Only one fragment Impact velocity of 0 to 1 650 m/s
Mechanical	9 Shaped charge jet impact	Residual jet of a shaped charge capable of nominal perforation of 300 mm thick steel plate

Some examples of behaviors are listed below to illustrate the interest of having to make the demonstration in a scope of stimuli, rather than by a standardized test:

For Slow Cook Off numerical simulation help us now to identify the great dependance of the ignition vocation, in a rocket motor or a warhead, on the heating rate.

For instance, a 60^0C/h heating rate can lead to ignition near the outer wall, while a 3.3^0C/h heating rate will lead to ignition in the center. This will have a great influence on the reaction violence, and will also be very dependent on the munition size and design.

TEMPERATURE PROFILES



Temperature profiles just before ignition, showing the influence of the heating rate on the ingition location

So, for a given munition, the heating rate can be chosen within the scope in order:

- to lead to the more critical situation, i.e. ignition in the center
- to allow, on another hand, the shorter test duration

The classical 3.3^0C/h requirement is probably the most severe condition, but can be well simulated by higher heating rates, depending on the munition size.

- For bullet impact, many experimental results have shown that the reaction violence may be different according to both bullet velocity and munition size and geometry:
  - concerning warheads with high explosive loadings there has been a lot of evidence that the situation where the bullet can be lodged in the munition is the worst case.

    Munitions with comp B are often detonating in this case while reaction may be only a type V when the bullet completely perforate the warhead.

    Even with PBX, type V reactions are quite often obtained with high bullet velocity while type IV reactions result from lower velocity impact.

    So the classical 850 m/s velocity required by most of the IM standards, which is near the nuzzle velocity, is not appropriate to identify the real reaction likely to occur

during operational life.

- concerning the rocket motors, some kind of propellants have led to detonation by a XDT mechanism, which occurs only under precise bullet velocity conditions, mainly depending on the grain geometry.

  Once again, the classical 850 m/s is not adapted to exhibit such a behavior.

- The same remarks could be done for fragment impacts which may lead to different reaction mechanisms according to their velocity. At higher velocity, the predominant mechanism is the detonation by SDT, but below the SDT threshold, a detonation is still likely by a DDT mechanism, which is similar to the behavior by perforating bullet impact.

  This means that testing one munition to the impact of one kind of fragment to just one velocity is not sufficient at all to screen all the behaviors that can occur.

4.2 The notion of "demonstration"

In addition to the fact that in most of IM Standards, the assessment of the behavior of a munition subjected to a type of Stimuli is only based on the result to a specific test, most of the time not more than three trials are performed. This also decrease the confidence level.

This is the reason why we decided in France that the assessment of the MURAT level has to be done not only by performing such a scale 1 test but on the basis of an established data file consisting of:

- simulations, using predictive tools

- a theoretical analysis of the predicted behavior of the munition when exposed to the different stimuli (particularly by lab scale testing on energetic materials)

- extrapolation of known reactions, (i.e. using generic hardware testing)

- results of tests judged representative of the required stimuli for which the characteristics are defined and validated by a justification record.

- The numerical simulation tools now available for munitions designers can help to identify the mechanism by which the reaction will be initiated in the energetic material:

  - heat transfer codes, associated to chemical reaction models if necessary, can predict when and where the reaction will be induced as a consequence of thermal threats,

  - hydrodynamic codes, also associated with reactive models, can inform wether or not a

reaction by SDT is likely to occur for bullet or fragment impact.

If not, the calculations can say wether or not the projectile will completely perforate the munition.

So it is possible to identify the most credible worst case according to the projectile velocity and weight (SDT, DDT or XDT in some particular configurations).

- Having identified the likely scenario of reaction of the energetic material, it becomes possible to define the properties which will be influential on the munition response violence. For instance:

  - a burning mechanism by the layer by layer mode, even under pressure up to l GPa, will prevent having a transition from burning to deflagration.

    This property will reinforced the confidence level for reaction less severe than type IV when a warhead will be exposed to a fuel fire.

  - good mechanical properties, associated with low burning quickness of damaged material, will also increase the confidence level for reaction less severe than type III to the impact by perforating projectiles, even if they are lodged in the munition. The friability test is pertinent for providing such information.

  - a low shock sensitivity, providing a safety marge compared to the maximum shock expected with high energy projectiles, and in sympathetic detonation configuration, will offer a guarantee of no detonation by these threats.

- The extrapolation of known reactions available for generic hardware or similar munitions can of course also bring a valuable support to both the mechanisms identified by numerical simulation and the properties recognized as important. Such information will also increase the confidence level for the result observed at a final scale one test on the munition candidate to a MURAT label. 15

5/ CONCLUSIONS

1 Thus, as it is done in the other major nations, France is introducing in its Forces the notion of Insensitive Munitions consisting of the possible assignment of MURAT labels.

In all existing or draft IM Policies, general requirement goals are very similar and are all going the same way: safety and reduction of hazards. Nevertheless, for France a fundamental criterion is the level of "safety guarantee" associated to such labels.

This guarantee can only be attained by applying the notions of "scope of stimuli" and

of "demonstration" for the assessment of IM candidates described in our Doctrine. This is why we are emphasizing this to be taken into account internationally.

2 One year after the ratification of the French Doctrine, the experience of such a progressive approach has shown that "MURAT" is not a dream.

- Munitions that can be labeled MURAT * are already available,

- because of existing R&D programs, MURAT ** will be developed in the near future and,

- even if they are not yet feasible, it is possible to say that MURAT*** is not an utopia.

So, owing to this Doctrine, were identified existing munitions showing an actual benefit in terms of hazard diminution and defined orientation for Research and Development of new technologies.